ISSN 1727-9917

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A benefit-cost analysis

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This document was prepared by Willard Phillips, Economic Affairs Officer, and Elizabeth Thorne, Research Assistant, Sustainable Development Unit, ECLAC subregional headquarters for the Caribbean.

United Nations publication
ISSN 1727-9917
LC/L.0210
LC/CAR/L.349

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Abstract

Waste management is one of the least recognized public policy issues in the Caribbean. Quite apart from the obvious physical unattractiveness of the business, waste management often competes with more pressing economic and social issues such as fiscal and trade matters, unemployment and poverty, education and health, and crime and security. Even within the domain of environmental sustainability, the management of waste has had to play second fiddle to more apparently manifest challenges such as land and coastal degradation, biodiversity loss, and climate change. Waste management, however, remains a major challenge for any society, since all natural processes generate waste. The particular economic, social and environmental circumstances of the Caribbean make this issue especially critical for medium- to long-term sustainable development. The present study therefore seeks to undertake a cost-benefit analysis of investment in waste management systems in the Caribbean, to assess the net economic effects of enhanced waste management and to identify opportunities for enhanced economic benefits through improved waste-stream management. The study uses a case-study approach and examines the issue in two Caribbean countries: Saint Lucia, and Trinidad and Tobago.

I. Introduction

Waste management is a major challenge for any society, since all natural processes generate wastes. It is important since it mitigates public health risks, contributes to sustained economic activity, and enhances public welfare. Waste management however is one of the least recognized public policy issues in the Caribbean. Quite apart from the obvious physical unattractiveness of the business, waste management often competes with more pressing economic and social issues such as fiscal and trade matters, poverty and unemployment, education and health, and crime and security. Even within the domain of environmental sustainability, the management of wastes has had to play second fiddle to more apparently manifest challenges such as land and coastal degradation, biodiversity loss, and climate change. The particular economic, social and environmental circumstances of the Caribbean make this issue especially critical for medium- to long-term sustainable development.

Adequate waste management is crucial in economic terms, since Caribbean economies are mainly natural resource-based, with tourism, mining, agriculture and fisheries being the dominant sectors. All of these economic activities can be significantly impaired by a deficient system of waste management. Both the physical beauty and pristine nature of the Caribbean attract up to 20 million cruise and stay-over visitors annually, making the tourism sector the main contributor to GDP and employment. At the same time, mining and agriculture contribute significantly to the generation of hazardous and other toxic waste, and have the potential to damage the natural environment. On the social side, overall economic growth accompanied by increased levels of urbanization and consumption have also resulted in increased generation and diversification of the waste stream, with rapidly growing challenges such as e-waste, toxic and

biomedical waste. The waste issue is also compounded by the reality that the Caribbean comprises mostly small island developing States (SIDS). Hence, the impact of poorly disposed waste is readily amplified through indirect pollution of groundwater and surface water, degradation of coastal and marine resources such as wetlands, coral reefs and fisheries, limited land space in which to site waste disposal facilities, limited human and institutional capacity for regulating and managing waste, and enhanced public health risks.

Given these concerns, there remains a considerable deficiency in the organization of, and investment in, effective national integrated waste management systems in the Caribbean. The present study seeks to undertake a benefit-cost analysis of investment in solid waste management systems[1] in the Caribbean, and to assess options for enhanced economic benefits through improved waste stream management. The study approaches this objective by examining two case study countries, Saint Lucia, and Trinidad and Tobago.

The study is organized into five sections. Section 1 reviews general global trends in waste management, as well as specific issues relevant to Caribbean small island developing States, and elaborates on possible options for enhancing waste management systems in the Caribbean. In Section 2, the economics of waste management are examined with special emphasis on the elements peculiar to the Caribbean. The benefit-cost analysis of waste management for the selected case study countries is detailed in Section 3. Recommendations for improving solid waste management in the Caribbean are summarized in Section 4. Limitations of the study as well as conclusions and recommendations are presented in Section 5.

[1] The subject of waste is a critical development issue. The focus of the study is specifically on the management of municipal solid waste systems in the Caribbean. Issues such as bulk or industrial waste, as well as waste water are not considered in the present study.

II. Global trends in waste management

Willard Phillips and Elizabeth Thorne [2]

Establishing the nature of waste is a reasonable point of departure for any discussion on the subject. Significantly, while the literature is quite extensive on the subject of waste management, there are relatively few efforts at defining exactly what constitutes waste. This is not altogether surprising, given the high level of diversity of waste, the complex social, cultural and economic dimensions which relate to it, and the constantly evolving technologies with which waste is treated.

According to Porter (2002), waste is stuff we don't want. In applying a decidedly economic element to this idea, Porter further elaborated that waste was "anything that is no longer privately valued by its owner for use or sale... ." Lacoste and Chalmin (2006) also acknowledged the complexity of defining waste. They observed that arriving at a definition typically involved the identification of a physical list of defined substances, along with a legal definition which identified "all substances that the holder (producer or owner) disposes of, or is obliged to dispose of."

On this basis, waste is generally broken down into broad categories which reflect the source of generation. Among these are household waste, industrial waste, construction and demolition waste, mining waste, and agricultural waste.

[2] Willard Phillips, Economic Affairs Officer and Elizabeth Thorne, Research Assistant.

Household waste is produced from daily household consumption, and includes food waste, paper, plastic, metal and glass containers from the packaging of domestic consumables, and used fabric from clothing, cleaning rags, and bedding, among others.

Industrial waste includes all materials generated from industrial production processes, and may include scrap metals, shredded wood, paper, plastics or other fabrics. Industrial waste may also include toxic material and liquids used in manufacturing, such as used oils and grease, acids, heavy metals, and other organic solvents. Many industrial processes are designed to capture and reuse waste, so that the recycling of industrial waste is often a significant aspect of industrial processes.

Construction and demolition waste derives from the erection of new buildings, or the refurbishment of old structures. This type of waste usually includes broken concrete, scrap wood and wood products, particle board, glass, old electrical materials, tiling and related masonry, old metal, and paints. Like industrial waste, construction and demolition waste is increasingly being recycled, especially in more developed countries.

Mining waste is often bulky, and results from the removal and/or relocation of overburden material such as soil or vegetation, in order to access minerals. Mining waste may also include sludge and slurries generated from primary processes such as pulverization, grinding, washing, or pumping of secondary materials. Other mining waste may also include spent material used in the mining process, such as explosives.

Agricultural waste is material generated from agricultural production and harvesting activities. This may include faecal matter from livestock production, green organic matter from fruit and vegetable production, and dried matter from the remnants of grain production and harvests. Waste from the agricultural sector may also be produced from the decomposition of bulk food harvests or contaminated material culled from food-crop infestations.

Some components of industrial, agricultural and mining waste are together broadly classified as hazardous waste. Household and other institutional waste, such as that collected from public offices, schools, hospitals and business places in urban and residential areas, are classified as municipal solid waste. The management of municipal solid waste is usually the responsibility of local governments, and in developing countries this function can consume between 20% and 50% of municipal budgets (Schübeler, 1996). Beede and Bloom (1995) summarize the process into the three basic components of collection and transportation, processing, and disposal. Collection and transportation is the function which gathers and removes solid waste from its source of generation. Processing modifies the physical characteristics of the waste in order to attenuate for its more offensive characteristics, reduce its threat to public health, enhance its disposability, and where possible, to extract any economic value from the waste. Processing usually involves functions such as recycling, composting, burning and compacting. The final stage of disposal serves to isolate and contain any remaining material after processing is complete.

All three stages make municipal waste management a complex task which requires a high level of organization and cooperation among several agents. These include households, communities, private enterprises and municipal authorities (Schübeler, 1996). Moreover, efficient municipal waste management requires the application of technologies and systems that undertake all tasks efficiently and, in the process, safeguard public health and promote aesthetically-pleasing spaces for society. The focus of the present study is on the management of municipal solid waste systems in the Caribbean. Issues relating to bulk or industrial waste, hazardous waste, or waste water have not been considered in the study.

A. Factors influencing global waste trends

In considering global waste trends, Lacoste and Chalmin (2006) noted that it was impossible to assess the volume of waste generated globally. They estimated the total volume of waste[3] collected globally to be between 2.5 billion and 4.0 billion metric tons in 2004. The estimate of the total volume of municipal solid waste within this amount was more accurately set at 1.2 billion metric tons for the same year. Notwithstanding the difficulty in estimating the overall quantity of generated waste, there are clear drivers which accounted for the global trends in total waste produced, the diversity of the global waste stream, and the potential for waste reduction and reuse through recycling.

The Swiss Federal Institute of Aquatic Science and Technology (EAWAG, 2008) noted that the amount of waste generated could be directly linked to income level and lifestyle. Income influences waste production, insomuch as the individual capacity to consume is enhanced with increased income, and increased consumption leads to increased waste-generation. The type of solid waste produced is also a function of human consumption patterns which is, in turn, reflected in their socio-economic characteristics (Berstein, 2004).

TABLE 1
ESTIMATED COLLECTION OF MUNICIPAL WASTE WORLDWIDE, 2004

Region	Municipal waste *(millions of metric tons)*
OECD countries	620
Commonwealth of Independent States [4] (Baltic States excluded)	65
Asia (excluding OECD)	300
Central America	30
South America	86
North Africa and the Middle East	50
Sub-Saharan Africa	53
TOTAL	1204

Source: CyclOpe, as cited by Lacoste and Chalmin (2006).

Using the share of collected municipal solid waste as a proxy, Lacoste and Chalmin (2006) showed the Organization for Economic Cooperation and Development (OECD) countries to have collected roughly 620 million metric tons of waste in 2004. This was followed by Asia with 300 million metric tons, and South America with 86 million metric tons. Significantly, the lowest quantities of waste collected were estimated for sub-Saharan Africa (53 million metric tons), North Africa and the Middle East (50 million metric tons) and Central America (30 million metric tons). These figures are summarized in table 1.

Income is also a key factor in waste collection, since higher-income countries typically collect a larger share of generated waste. Most high-income countries collect over 80% of generated municipal solid waste. Middle-income countries collect between 50% and 80%, while low-income countries range between 30% and 60% (Cointreau, 2006).

Population size is also a factor in waste generation, and since this varies considerably among countries, waste generation per capita is also an important indicator for comparing waste production among countries. In this regard, high-income countries also have higher waste production per capita compared to poorer countries. Lacoste and Chalmin (2006) showed that the United States of America

[3] This includes global estimates of industrial waste, but excludes construction and demolition, mining and agricultural waste.
[4] CIS –Commonwealth of Independent States. This grouping was formed subsequent to the break-up of the former Soviet Union between 1989 and 1991.

collected the highest quantity of waste per capita among all western countries, at more than 700 kilograms per capita per year in 2004. This was followed by Australia and Western Europe with 600-700kg per capita, while other industrialized countries such as Japan, Korea and Eastern Europe collected 300- 400kg per capita in 2004. China[5] and Turkey were assessed to collect some 500kg per capita in the same year.

Latin America, in contrast, recorded significantly lower per capita waste collection rates, with the major cities in Argentina and Brazil averaging between 200 and 300kg per capita per year. Even lower figures were estimated for Nairobi, Kenya (220kg per capita) and Mumbai, India (120 kg per capita) in 2004.

Yet another key factor which influences waste generation is the level of urbanization. According to UN-HABITAT (2010), half of the world's population had already been urbanized by 2010. Moreover, while Asia and Africa are currently the least urbanized regions, countries in these regions are projected to attain more than 50% urbanization of their populations by 2030. The largest share of urban growth over the past 30 years took place in developing countries, and it is expected that, by 2017, the developing world would have a larger share of urban population compared to rural dwellers (Cohen, 2006).

There is a direct relationship between economic growth and urbanization (UN-HABITAT, 2010). Furthermore, since economic growth leads to increased incomes, urbanization is, in turn, a key driver of the generation of waste. This is because urban populations generally consume more, and with the high premium cost of space in cities, are inclined to dispose of more trash compared to rural populations. Achankeng (2003), for example, in a case analysis of several African cities, noted an average waste generation per capita per day of 0.78 kg, compared to 1.22kg per capita per day for cities in more developed, urbanized countries.

B. Trends in global waste diversity

Not only is there an upward trend in the quantity of waste generated and collected globally, but there is also an observable trend in terms of the diversity of the waste stream between developed and developing countries. Although municipal solid waste generally contains higher proportions of organics and paper, poorer households generate larger shares of organic waste compared to richer ones.

A similar pattern holds for rural households compared to their urban counterparts (EAWAG, 2008). The consumption of larger quantities of processed food and packaged items in richer countries, and the fact that higher rates of urbanization are more likely, explain these differences. This holds significant implications for the approach to, and cost of, waste management across countries. The higher proportion of organic matter in the waste streams of developing countries increases handling costs for collection, as this kind of waste is often more bulky. Moreover, higher organic content increases the potential for the breeding of rodents and other vermin, the fostering of mal-odours, and concomitant public health risks. It also reduces the prospects for incineration as a waste-disposal strategy. Nevertheless, waste with high organic content also provides good opportunity for the production of methane when buried in a landfill, and is also suitable for the production of soil-enriching manures when composted.

The higher share of cardboard, paper, plastics, glass and metals in the waste stream in developed countries makes waste reduction strategies such as recycling, and waste-to-energy and waste disposal methods such as incineration, more technically and economically feasible. Table 2 summarizes key differences in waste diversity between developed and developing countries.

[5] Lacoste and Chalmin (2006) noted that in recent years, China has adopted a decidedly Western lifestyle in many of its urban areas, which has resulted in an increase in its generation of municipal solid waste. EAWAG (2008) noted that newly-industrialized nations like China and India now confront enormous solid waste management challenges which will severely strain municipal finances and handling capacity in the foreseeable future.

TABLE 2
TYPOLOGY OF MUNICIPAL WASTE COLLECTION AND TREATMENT BY COUNTRY INCOME
(Percentage)

Composition of municipal waste *(Percentage)*	Low-income countries (India- Egypt-African countries)	Medium-income countries (Argentina-Taiwan- Singapore-Thailand- EUNMS)[a]	High-income countries (United States of America-European Union-Hong Kong)
Food/putrescible waste	50- 80	20 - 65	20 - 40
Paper and cardboard	4 – 15	15 – 40	15 - 50
Plastics	5 – 12	7 – 15	10 – 15
Metals	1 – 5	1 – 5	5 - 8
Glass	1 – 5	1 – 5	5 - 8

Source: Extracted from Lacoste and Chalmin (2006).

[a]. EUNMS: European Union new member States.

C. Global approaches to solid waste management

In discussing a global perspective on solid waste management, it is useful to examine the regime of approaches employed by mankind to manage solid waste. Historical accounts on waste management suggest that waste disposal methods such as open dumping, burning, burying – a rudimentary form of land filling, and composting were practiced from as early as 2000 BC by both the Chinese and the Greeks (Environmentalists. Every Day, 2011). Additionally, early recycling and reuse methods were found to be practised by many peoples, including the Mayan Indians, up to around 250 AD.

The real challenges of waste management, however, did not become apparent until the industrial revolution spawned the rapid growth of cities, with its accompanying concentration of population and waste production. Subsequently, broader approaches, such as the formal organization of waste collection systems, the setting up of regulatory frameworks, and new disposal methods, came into practice. Today, the most widely employed waste-management strategies include open dumping, landfill practices, incineration, composting and waste reduction (which includes waste reuse and recycling).

1. Open dumping

Open dumping was one of the earliest methods of waste disposal to be practised by humans. Waste materials such a food scraps and animal bones were simply dumped in small holes around the living compound. Subsequently, as villages grew and the quantity of waste increased, households dumped their waste on open plots, or in low-lying areas and other public spaces such as rivers or swamps (EAWAG, 2008). Fire was also often used as a method of disposal of accumulated waste in open dumps, and was first practised in household backyards. Not unexpectedly, open dump sites were the source of numerous public health hazards, as they served as breeding ground for insects, rodents and other disease-carrying vermin. Additionally, the open decay of organic material produced additional nuisances, such as foul odours. With the eventual establishment of open municipal dumpsites, burning also became commonplace, resulting in further health risks through pollution of the air by ash and other ambient toxins. Although open dumping was widely employed in many developing countries, its application as a waste-disposal method has declined substantially in recent decades, and is now significantly replaced by the use of landfills as a means of disposing of municipal waste.

2. Landfill practices

While the burial of waste as a disposal strategy was practiced among ancient civilizations, the municipal landfill evolved in response to the issue of open dumping and burning described previously. Over time, two types of landfill emerged. The first and earliest developed where municipal agents took the decision to systematically cover the waste in open dumps with soil. These 'upgraded dumpsites' were therefore improvements to the open dump, since the soil cover mitigated the growth of vermin and controlled for foul odours and other negative consequences. Upgraded dumpsites also eliminated the need for burning as a waste-disposal method. Still, the coverage of waste by soil led to other complications, chief of which were the production of methane gas by anaerobic[6] decomposition, and the production of toxic leachate[7] which could contaminate groundwater sources. Due to these challenges, upgraded dumpsites often posed the risk of spontaneous combustion of gases leading to fires which were extremely difficult to control or extinguish in landfills. On this basis, new design standards and regulations for the operation of landfills were enacted in the United States of America in the 1970s, leading to the development of a second type of landfill, known as the 'sanitary landfill'. As noted by Porter (2002), the enhanced design elements included the implementation of protective lining and piping at the base of the landfill in order to prevent groundwater seepage, as well as to collect generated leachate. Other engineering elements included the construction of collection ponds for the treatment of leachate before being released into surface water systems, and the installation of tubes to vent any methane gas produced. Further operational standards required that all waste deposited in the sanitary landfill be buried on a daily basis. All these requirements significantly increased both the establishment and operational costs of sanitary landfills, and resulting economies of scale triggered a reduction of the total number of landfills in many countries. In the United States, for instance, the number of landfills declined from roughly 20,000 in the early 1970s to barely 2,000 operations by 1998 (Porter, 2002). Additionally, this change saw the elimination of many small, inefficient landfills, and the growth of the remainder into mostly privately-owned mega-operations. While similar forces were at work in Europe during the later half of the twentieth century, many European countries turned to incineration as a waste-disposal strategy. At the same time, some developing countries have adopted enhanced landfill practices, having established a mix of both upgraded and sanitary landfills. However, the use of open dumps remains the principal waste-disposal method in many developing countries.

3. Incineration

Incineration is the controlled burning of large quantities of municipal waste in specially-engineered facilities. Incineration is perhaps more of a waste-reduction than a waste-disposal technology,[8] since it results in a disposable ash amounting to between 20% - 30% of the initial volume of waste (Porter, 2002). Several factors influence a country's waste management policy in the direction of incineration, and these factors manifest themselves in different ways across the globe. Lacoste and Chalmin (2006) observed that incineration was more commonly applied in Europe compared to North America, mainly because of relatively scarcer land space, and higher landfill costs. Additional dynamics, such as the rate and level of economic growth, household expenditure, the prevailing regulatory framework, environmental awareness, and the evolution of secondary materials markets, also played a role in shaping a country's acceptance of incineration.

[6] As a consequence of the waste coverage by soil, the decay of organic matter takes place in the absence of oxygen, thus leading to the production of highly flammable methane (CH_4) gas as a by-product.

[7] Leachate is a solution formed by leaching, and usually contains contaminants picked up through the movement of liquids through the soil.

[8] As pointed out by Porter (2002), not all trash burns, and efficient operation of an incinerator normally requires the removal of glass and metals, either before or after burning. This, as well as eventual ash which remains after combustion, needs to be subsequently disposed of, usually in a landfill.

Early incineration was motivated by the simple premise of getting rid of waste. This requirement led to the establishment of incinerators in the United States of America in the 1960s, but their development soon ran afoul of the United States environmental lobby. The proclivity of incinerators to pollute at will raised such concerns as air pollution and the possible toxicity of incinerator ash (Porter, 2002).

Subsequently, rising prices for fossil fuels in the 1970s, along with concerns over the cost of landfill operations in the 1980s, led to a renewed thrust in incineration, this time with the objective of recovering energy from the burning of waste – the new waste-to-energy approach. Notwithstanding this development, the relatively more available land space in the United States served to dampen investment in incineration so that today, less than 20% of municipal waste is incinerated in the United States while more than 30% is incinerated in selected European countries[9] (Lacoste and Chalmin, 2006).

Incineration has not been widely employed as a waste-management strategy in developing countries. This is due to the high capital cost of establishment, the need for large volumes of waste in order to be scale efficient, and the secondary environmental impacts, such as air pollution. Additionally, the high degree of organic matter, and therefore of moisture content, does not facilitate the efficient burning of such waste in incinerators. A possible exception, however, was noted by Zerbock (2003), who pointed out that, in small island nations where space for landfills was at a premium, modular[10] incineration technology might be practicable. This option was enhanced where incineration offers waste-to-energy possibilities for typically energy-insecure small island States. Nevertheless, other externalities – such as high transportation costs to supply minimum required waste volumes, high operational costs, and the need to subsequently dispose of incinerated ash (perhaps even in a landfill) – appear to have cast doubt on the feasibility of incinerators in developing countries.[11]

4. Composting

Unlike incineration, composting is a waste-management technology that is more suitable to the high organic matter content typical of the waste streams in developing countries. Composting is the controlled biodegradation of organic waste to yield soil-enhancing material which may be used for agriculture. According to EAWAG, (2006), efficient composting can result in reductions of between 50% - 80% in waste volume. Composting is practiced, to varying degrees, in different waste markets around the world. In Asia, for instance, composting is widely used both in municipal and rural areas as a means of waste disposal and reduction. In rural areas, the practice is principally a small-scale, backyard-type arrangement, while within urban areas, centralized composting plants have been established. The practice is also more commonly employed in Europe compared to North America, and centralized plants have also been tried with varying degrees of success in Latin America.

Although rudimentary composting facilities are quite cheap to set up, centralized facilities have generally high operating costs, as well as low demand for produced compost, factors which explain the failure of such facilities in many municipalities in developing countries. Moreover, efficient operation requires good management, supported by ancillary services for efficient waste source separation, in order to guarantee that high quality, non-contaminated organic materials are supplied to the composting plants (UNEP, 2011).

[9] These include Switzerland, Sweden, and Denmark.

[10] The United Nations Environment Programme (UNEP) described two types of incinerator technology: (1) Mass Burn, which required daily waste capacities of between 100 – 3,000 tons to be scale efficient; waste is burned in common chambers, where almost all types of waste are accepted. (2) Modular incinerators process between 5 – 120 tons per day and are designed to be expanded and operated on a modular basis, with multiple units being used at a single site.

[11] Developed island nations [Singapore (65%), Taiwan (60%) and Japan (75%)] incinerate a significant share of municipal waste (Lacoste and Chalmin, 2006).

5. Recycling

Across the ages, recycling has moved from a routine necessity among humankind to a norm that is today practiced within a considerable, and often complicated, economic and regulatory framework, especially in developed economies. This trend reflects the changing pattern in the availability and value of recycled material over time. The relative scarcity, reflected in the high cost, of primary materials during the pre-industrial era made it profitable for households to specialize in the recovery of most materials, thereby creating welfare-earning opportunities for scavengers and early waste pickers, known then as 'rag and bone' men (Lacoste and Chalmin, 2006). As the industrial revolution made it possible to extract primary materials more easily, and to manufacture others, recycling lost its incentive in many households, only to regain its importance during the latter half of the twentieth century. Even today, this dynamic remains apparent when recycling is considered in a global context. As observed by Porter (2002), while recycling in the United States and Europe needs to be encouraged by a regime of non-market activities and policies, it has rapidly emerged as a market-driven, for-profit activity in many cities of the developing world.

Recycling is ostensibly a waste-reduction strategy, and the now classic recyclables include metals, paper, plastics and glass. The percentage of municipal solid waste recycled varies widely across the globe and is strongly influenced by other prevailing waste-disposal approaches, as well as socio-cultural and economic circumstances and attitudes. In Europe, for example, between 20%-30% of total municipal waste is recycled, while in lower-income, developing countries, this figure ranges between 5% -15% (Lacoste and Chalmin, 2006). The share of recyclables also varies, both for specific types of waste, and for particular countries. Hence, in Switzerland, up to 80% of polyethylene terephthalate bottles (the ever-popular plastic or PET bottles) are recycled, compared to 40% in the United States (BBC, 2005). In contrast, Japan, recycles a mere 5% of municipal waste, since the majority of its recyclable waste is incinerated (Porter, 2002).

The economics of recycling is tenuous, particularly since recycling itself provides no direct incentive to households, costs tend to be high, the process is labour-intensive, and the prices of recycled materials tend to be low and highly variable (Porter, 2002). Although the practice has evolved to varying degrees in many developed societies, recycling is often sustained at high social cost, given the need for an enhanced policy and regulatory framework to drive it. Nevertheless, large labour surpluses in developing economies encourage more economically-efficient recycling. Still, technological constraints from limited manufacturing scope, externality factors such as public health risks to low-earning waste pickers, and limited domestic markets for recyclables, make this business difficult even in developing economies.

D. Key reasons for solid waste management

Notwithstanding the many challenges associated with the above approaches to municipal waste management, a key question is why at all this is important. Solid waste management is critical in mitigating risks to public safety, as well as in the prevention of environmental degradation. Environmental and health concerns linked to solid waste include: increases in disease vectors and vector-borne diseases;[12] explosive gases; air pollution, including toxic emissions; nuisances, such as odour, litter, dust, noise and scavenger birds; public safety; landfill gas migration; surface water, groundwater and marine pollution; and leachate generation. These broad threats are deemed to be the key reasons for effective municipal solid waste management.

[12] Leptospirosis, dengue fever and gastroenteritis

Disease vectors

Improperly-disposed municipal solid waste provides the perfect environment for the breeding of rodents, flies and other vermin. Although detritivores[13] are essential organisms for breaking down complex organic materials in the decomposition process, it is important to manage their population since they contribute to the spread of several related diseases.

Explosive gases

As garbage in landfills undergoes microbial decay and other chemical reactions, landfill gas is produced. Depending on the waste composition and the structure of the landfill, this gas builds up pressure under the surface, thereby creating a high incidence of fires and release of toxic fumes. Landfill gas also has traces of nitrogen, oxygen, water vapour, sulphur and other contaminants. It is for this reason that solid waste management should be well designed, with adequate systems for the monitoring and control of the emission of landfill gases.

Air pollution and other environmental nuisances

Air pollution is caused by the emission of gases, dust, smoke and odours. Other environmental nuisances that must also be managed are noise, litter, and the proliferation of specific bird populations. The generation of toxic emissions may also be a key contributor to public health risks, and should be controlled as part of the overall municipal waste management effort.

Landfill gas migration

Gases are extremely mobile once there is nothing to constrain their movement from an area of high concentration to an area of low concentration. Landfill gas may therefore migrate to areas in close proximity to landfill sites, thereby creating potential health hazards such as respiratory diseases, or even explosive conditions. Moreover, landfill gases are a significant contributor to greenhouse gas emissions with related implications for their contribution to global climate change. This issue is developed further below.

Leachate generation/ Surface and ground water pollution

Leachate is produced when rainwater percolates with liquids created from decomposing waste in an anaerobic environment. It has the potential to travel through the soil layers to the water table, ultimately contaminating groundwater resources which, in turn, contribute to land-based sources of pollution to the marine environment. Leachate consists of aromatic hydrocarbons (benzene and toluene), chlorinated benzenes, volatile halocarbons, phenols, and various carboxylic acids. These contaminants may cause major public health risks to exposed populations.

E. Global waste management and climate change

The approach to waste management around the globe also has a significant impact on global warming and climate change. This is because a number of waste disposal methods are themselves significant producers of greenhouse gases (GHGs) which have been identified as the cause of global warming. While contemporary thinking on global warming focuses on carbon dioxide (CO_2) as the main offender, other GHGs such as methane (CH_4), water vapour (H_2O), and nitrous oxide (N_2O) are certainly more important drivers of global warming from a waste management point of view. Methane is produced in considerable quantities from the decomposition of organic waste in municipal landfills, and is deemed to have around 21 times the global warming potential of CO_2 (EPA, 2002; Porter, 2002). Furthermore, other waste reduction and disposal methods, such as composting, incineration, and even open dumping, also generate GHGs such as nitrous oxide and water vapour, in addition to carbon dioxide.

[13] Detritivores are organisms that feed on and break down dead plant or animal matter, returning essential nutrients to the ecosystem. They include micro-organisms such as bacteria, as well as larger organisms such as fungi, insects, and worms.

Williams (2009) noted that global waste production was predicted to double over the next 20 years, driven by increased urbanization and greater waste generation per capita in emerging economies. This overall increase in the generation of municipal solid waste globally, along with evolving waste management strategies, particularly in developing countries, holds the potential to exacerbate the climate change challenge which confronts humanity over the medium to long term. .

F. Particular solid waste management challenges for Caribbean Small Islands Developing States

Although recent figures are unavailable for most countries, solid waste generation for the Caribbean was estimated at between 27,000 to 945,000 metric tons in 2005, with daily per capita waste generation rates ranging from 0.7kg to 2.8kg (Binger, 2011). Additionally, at the 2008 Fourth Annual International Coastal Cleanup Conference held in Montego Bay, Jamaica, it was reported that a total of 6,781, 537 items of garbage had been collected from Caribbean coastal areas, 90% of which were from land-based sources (Al Binger, 2011). While these figures reflect, in part, a broader global challenge, the management of solid waste in Caribbean small island developing States is rendered all the more demanding given their spatial limitations, which exacerbate other concerns such as population density and competition for land use. Other related constraints include limited natural, human and financial resources, the unavailability of scale-efficient technologies, highly open, trade-dependent economies, weak institutions and weak governance. These are issues not peculiar to the Caribbean but rather, applicable to small island developing States around the globe.[14]

The scarcity – and, therefore, cost – of land for landfill sites of municipal waste is possibly the most obvious constraint, since landfills are overwhelmingly the most widely-used waste disposal method in the Caribbean (De Cuba and others, 2008). Land availability apart, small islands also face the challenge of choice of optimal location. Given that most built developments and settlements are in the coastal zone, Caribbean countries are often forced to establish landfills in the coastal area in order to minimize per capita waste haulage costs, as well as take advantage of more level coastal terrain for disposal. Coastal landfill sites pose environmental threats through leaching to other coastal resources such as beaches, reefs, wetlands and groundwater sources, all of which are important for both local populations and the vital tourism sector.

The shortage of human talent is another key constraint in Caribbean small island developing States, as small island populations cannot typically support the range of technical skills necessary to plan, implement and monitor waste management systems. Furthermore, the generally weak fiscal position of many Caribbean States, coupled with high public debt, places severe limitations on the resources available for public sector investment (Perez Caldentey, 2007). In a situation of scarce financial resources, municipal waste management does not generally figure prominently on the list of social priorities such as health, education, employment and national security.

Municipal waste management in the Caribbean is also constrained by the unavailability of scale-efficient technologies for the collection and disposal of waste. Indeed, this is a challenge for all SIDS, and possibly explains the dominance of landfills on small islands since, as noted by Porter (2002), the landfill is the most scale-efficient disposal method. Such scale efficiency is often not attainable with waste collection technologies such as standard garbage compactors, as the fuel and labour inputs generate high per capita collection costs for small Caribbean municipalities. The lack of appropriate technology, among other factors, has also precluded the application of other waste-management approaches such as incineration, composting, waste-to-energy applications, and material-recovery

[14] In addition to the Caribbean, SIDS include the Pacific Region (with the Cook, Marshall and Solomon islands among them), and the Africa, Indian Ocean, Mediterranean and South China Seas Region (AIMS), (with the Maldives, Seychelles, and Cape Verde islands among them).

technologies in waste recycling. This is because small populations cannot generate the required volumes of waste to make it feasible for the capitalization and operation of such technologies.

Openness and high trade dependence of Caribbean economies is another factor which poses a challenge to waste management in the Caribbean. This challenge derives from the inability of small nations to effect domestic policies which can have any bearing on waste management policies in source countries. Caribbean Governments cannot influence the decisions of manufacturers in industrial economies with respect to the percentage and type of packaging material used for imported consumables. Possible actions in this regard are to be limited to the imposition of fiscal levies as a mechanism to dampen import demand. While this has the effect of driving up domestic prices, it does not create any incentive to reduce packaging content in international source markets. Furthermore, in economies where most consumable items are imported, the characteristics of domestic waste streams are determined, to a significant degree, by external waste-reduction policies. Trade dependence also implies that the tastes and preferences of Caribbean consumers are shaped by consumption patterns in source countries, with the resulting waste eventually presenting particular collection and disposal challenges to domestic waste managers. Two notable examples are the widespread consumption of bottled water and the resulting impact of plastic bottles on the environment, and the increased importation of reconditioned products such as motor vehicles, which have placed additional pressures on the capacity of Caribbean countries to collect and dispose of waste (Treasure, 2011).

The structure of Caribbean economies also presents particular challenges for the management of municipal solid waste. In addition to growing rates of solid waste generation per capita, stop-over tourists are reported to generate at least twice the amount of waste as local residents, while cruise ship passengers generate up to four times the amount generated by local residents (Binger, 2011). Ironically, this situation contributes to the precarious nature of Caribbean economies, since more environmentally-sensitive visitors are inclined to choose a different destination if they observe environmental degradation, caused by poor solid waste management practices (Dragan, 2000).

Yet another challenge emerges in the context of the institutional and governance framework for municipal waste management in the Caribbean. Schübeler (1996), in assessing the institutional aspects related to effective solid waste management in low-income countries, observed the need for certain important prerequisites: appropriate distribution of responsibilities and revenues; adequate capacity-building measures; private sector involvement; and the recognition of informal waste-collection workers. These conditions are assessed to be largely deficient in solid waste management systems in the Caribbean. Squires (2006) summarized the main institutional challenges for selected Caribbean countries over the period 1994-2005, as follows:

- Poorly located dumps around the country
- Uncontrolled scavenging
- Regular burning
- Inadequate management and maintenance of solid waste systems
- Inadequate budgetary allocation by Central Government to the line ministries
- Weak legal and regulatory framework and inadequate institutional capacity
- Inappropriate, inadequate vehicular equipment
- Inadequate management of hazardous waste
- Low public education and limited awareness of solid waste management issues
- Inadequately serviced populations

Weak governance structures in small Caribbean States also impose special challenges on the marine environment. Solid waste management failures readily manifest themselves through coastal pollution of the Caribbean Sea from land-based sources. The Caribbean Sea has been designated as a Special Area under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), and is afforded special protection under the Cartagena Convention. As signatories to these multilateral agreements, Caribbean Governments hold legal obligations to prevent pollution, either from land-based sources or from ships. Thus, high standards of municipal waste management are an imperative for the Caribbean. One positive response has been the implementation of the Organization of Eastern Caribbean States (OECS) Solid and Ship-Generated Waste project, discussed further below.

Despite these seemingly insurmountable concerns, the Caribbean understanding of solid waste management has been changing, albeit slowly, over the years (Solis-Ortega Treasure, 2011). Barbados, Jamaica, and the Bahamas have secured external funding to improve their waste management infrastructure and to develop their legal and regulatory frameworks. Saint Kitts, Saint Lucia and Dominica have developed individual country legislation to address solid waste management. In Barbados, an integrated solid waste management programme is being executed (CSD, 1998). Finally, several countries have agreed to allow the Caribbean Environmental Health Institute (CEHI) to monitor the environmental parameters for the operation of landfills (CSD, 1998).

III. The economics of solid waste management

In developing economies, most strategies for the improvement of solid waste management systems take the form of technical or institutional interventions. These typically include the acquisition of new waste collection machinery, the enhancement of old, or the development of new landfill sites, and the establishment or re-organization of national and municipal waste management agencies. Often, these developments take place without sufficient recognition of the economic parameters which motivate behaviour among diverse economic agents in waste generation, reduction and disposal activities. This section presents a brief discourse on the economic and policy issues which attend the business of solid waste management.

Waste is generated as a result of the two economic activities of consumption by households and production by firms. In the classically-organized economy, consumers utilize goods and services in order to maximize their individual satisfaction or well-being, while firms produce goods and services in order to maximize profits. All waste generated represents a form of dissatisfaction to both consumers and producers, either because it may be a health threat, may produce other nuisances such as bad odours, or may reduce environmental aesthetics. In producing firms, generated waste may reduce profits due to congestion, or it may occupy useful space and reduce overall productivity. Waste therefore represents a disincentive to economic activity, and consumers and producers seek to dispose of it at minimal cost. This is consistent with the utility-maximizing or profit-maximizing objective of all economic agents.

Since all agents seek to rid themselves of waste at the lowest possible (usually zero) cost, there is a high incentive to dump waste

indiscriminately. When all individuals act accordingly, society rapidly confronts the social challenges and threats of poor waste management. Porter (2002) described this situation as a market failure in which there was a missing market for waste – no one in the economy was demanding waste material. Moreover, even where such demand might exist, as in the case of recyclable materials, recycling markets are very unstable, and subject to dramatic and irregular price and supply shifts. In such situations, poor price signalling from the market results in inefficient allocation of resources for the management of waste.

For example, a household in a rural area may chose to bury or burn its domestic waste since, as an unwanted 'good', this method of disposal is the least-cost option in terms of time and effort to the household. Similarly, in urban municipalities, households may be prepared to put out domestic waste for free collection by a municipal agency. If, however, the society wished to undertake waste reduction strategies through recycling or composting initiatives, there would be no specific incentive to households to undertake the related activity of source separation, unless some incentive in the form of a subsidy were offered by the market to do so, or a disincentive in the form of a tax was imposed on current waste disposal activities.

The matter of subsidies and taxes comprises the core element of economic policy with respect to municipal waste management. Taxes as waste production disincentives may be imposed in the form of tipping fees for the disposal of waste in landfills, per unit fees for household waste collection by municipal agents,[15] or through deposit refund systems which encourage the recycling of selected packaging materials.[16] Indirect taxation for waste management may also be imposed via more generalized environmental taxes and levies, from which revenues a portion may be used to finance municipal and national waste management activities.

In the case of tipping fees, waste disposers may be charged a fee per truckload of waste deposited at a landfill. While this fee might vary significantly, Porter (2002) noted that, between the 1980s and 2000s, tipping fees for the 100 largest cities in the United States doubled, to reach an average of US$ 36 per ton during the mid-1990s. More recent estimates by the United States Waste Business Journal (2010) put average waste tipping fees in the United States at US$ 44 per ton, representing a 6% increase over 2009 figures. However, tipping fees do not fully cover the real cost of landfill disposal, since there are other externality costs such as odours, dust, heavy machinery traffic, vermin and smoke, as well as the ever-present threat of contamination of groundwater sources. When such costs are included, Porter (2002) reported a range of real tipping fees of between US$ 45 – US$ 75 per ton of disposed waste for the United States in the early 1990s. Tipping fees cover the marginal variable costs incurred in interring a ton of waste,[17] as well as the marginal capacity of the landfill used up in the disposal of each ton of waste. This second cost element effectively represents the relative scarcity of land for landfill disposal operations since, as a landfill becomes used up, its effective lifespan is reduced, thereby making the need for land for a new landfill more urgent. The impact of relative land scarcity on tipping fees is immediately apparent in smaller countries. Hence, in Germany and Japan for instance, tipping fees in the early 1990s ranged from US$ 300 - US$ 400 per ton (Porter, 2002).

Per unit waste disposal fees or volumetric and/or flat tariffs have also been used by many municipal governments in developed countries as a disincentive for consumers to generate waste. Beede and Bloom (1995) noted that these charges motivated firms and households to reduce residual waste, either by changing the way they produced and consumed waste, or by recycling, illicitly dumping or burning waste. Such charges are often levied as unit charges per volume of trash placed at the kerb for pickup, or as a direct tax on each household. These charges are normally used to cover the cost of collection, transportation, processing and disposal of municipal waste. Empirical studies by Reppeto

[15] This so-called "pay as you throw" arrangement charges households for each unit of trash put out for collection. It anticipates that, as user fees increase with volume of waste, consumers have an incentive to reduce waste volumes by engaging in other household disposal methods such as composting, or by reusing waste through recycling.

[16] Deposit refund systems are typically set up in order to stimulate the reuse and/or recycling of beverage containers.

[17] This includes digging, pushing, lining, and covering. It may also include the cost of procuring special landfill cover if this is sourced from outside the landfill area, as might be the case with landfills containing hazardous waste.

and others (1992), as cited by Beede and Bloom, showed that per unit disposal fees, when combined with a waste recycling collection programme, resulted in an average reduction of municipal waste of more than 30% in the United States[18] between 1980 and 1989.

While per unit charges are not widely applied in developing economies, Beede and Bloom (1995) have suggested that this might be a very effective way for cities in developing countries to finance municipal waste management services. This is because the approach is likely to reduce the incentive for illegal dumping, and possibly provide an avenue for subsidizing waste collection services in poorer neighbourhoods, an issue which is a particular challenge in developing countries. Moreover, there might be no need for tariffs to be supported by a recycling programme since, typically, most recyclables would already have been removed before household waste was put out for collection.

Deposit refund systems are used as incentives to encourage the recycling of beverage containers, thereby reducing the occurrence of illegal dumping. The systems operate by imposing a special 'front-end' charge or deposit on consumers at the time of purchasing goods sold in reusable containers. The consumer can subsequently collect the deposit as a refund upon returning the container for recycling or disposal (Portney and Stavins, 2000). Although the mechanics of the system may vary with the type of product, Portney and Stavins (2000) noted that deposit-refund systems were likely to be most appropriate where there was widespread incidence of illegal dumping, and where the social cost of such dumping was high. In this regard, the size of the deposit would be set based on the social cost which arose from the illegal disposal of the packaging for the product. Beede and Bloom (1995) also observed that the operational cost of a deposit-refund system could be lower than the overall cost of remediating illegal dumping, especially where the number of illegal dumpers was high.

One of the challenges in setting economic policies through taxes for waste management is in determining the appropriate level of tax. If the tax level exceeds the marginal social benefit, then consumers have an incentive for tax avoidance by engaging in illegal dumping and/or littering, with concomitant higher costs to society in the form of compromised physical aesthetics, and increased public health risks. At the same time, too low a tax level may not provide sufficient incentive for waste reduction and recycling. Moreover, there are circumstances under which taxes as disincentives to unwanted consumer behaviour simply do not work (Porter, 2002). It is in such situations that subsidies may be used to encourage alternate waste management behaviour. These are especially useful on the production side of the economy, where firms may receive subsidies to undertake more environmentally-safe disposal methods, especially where waste disposed into the environment can pose a serious public health threat. Some examples of waste subsidies include the payment of overtime pay to waste collectors to complete route collections, or the payment of a full day's pay even when employees complete route collections early in the day (Porter, 2002).

Although taxes and subsidies are widely applied to influence the evolution of waste management in developed economies, they have found relatively little application in developing countries and less in Caribbean SIDS in particular. Since 1992, several Caribbean countries have enacted generalized environmental legislation in order to promote protection and conservation of the natural environment (United Nations Environment Programme (UNEP), 2002). However, only a few elements of such legislation have provided for the implementation of fiscal and other regulatory policy in the specific case of solid waste management. Huber, Ruitenbeek and Seroa da Motta (1998) identified three Caribbean countries — Barbados, Jamaica and Trinidad and Tobago — in which waste fees and levies, deposit-refund schemes and taxes and/or tax relief[19] for solid waste management activities were either being implemented or were under consideration. Additionally, an environmental levy of US$ 1.50 per visitor

[18] This study was based on a sample of fourteen municipal communities in the United States of America.

[19] The regimen of taxes implemented in the Caribbean is highly varied. In some countries, a specific environmental levy or green tax is imposed (as in the case of Trinidad and Tobago), while in other cases, more general levies for impacting the natural environment (such as through waste disposal) have been applied.

was being charged to stay-over and cruise visitors to those countries comprising the Organization of Eastern Caribbean States.[20]

Significantly, tipping fees for solid waste disposal are increasingly being utilized in the Caribbean. In the case of Barbados, a charge of US$ 20 per ton is imposed on waste deposited in landfills (UNEP, 2011). Moreover, several OECS countries have also implemented tipping fees ranging from US$ 40 to US$ 108 per ton for marine waste,[21] and between US$ 1.90 and US$ 20.75 per ton for other categories of waste. Notwithstanding, there has been reluctance to implement these fees across the Caribbean because of the possibility of increased illegal dumping of solid waste (Awe, 2005). Some countries also apply direct user fees for municipal waste collection in the Caribbean (UNEP, 2002).

[20] These countries include Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines. Anguilla and British Virgin Islands are associate members.

[21] Between 1997 and 2003, OECS implemented a Solid and Ship-Generated Waste project in order to strengthen its capacity to receive solid waste generated by cruise ships. This marine waste is disposed of in local landfills for an often substantial tipping fee.

IV. Benefit-cost analysis – Case studies

This section examines the profile of benefits and costs of undertaking municipal solid waste management in the Caribbean. While the scarcity of relevant waste management data makes this a decidedly cursory analysis, it is anticipated that this assessment could make a preliminary economic case for increased public sector investment in municipal solid waste management in the Caribbean.

A. The approach to benefit-cost analysis

Municipal solid waste management involves the collection, transportation, processing and disposal of waste. Much of the literature on benefit-cost analysis focuses on the impact of the processing stage on society, with particular emphasis on waste reduction and disposal activities. Indeed, several studies focus exclusively on recycling, with the degree of complexity of the analysis being related to the extent of the development of waste management operations, as well as the availability of relevant data.

One such study was completed by COVEC Consulting (2007) for the Government of New Zealand. It involved a detailed analysis of the benefits and costs of recycling paper, plastics, glass, organic waste, construction and demolition waste, tyres and used oil. The study employed a marginal cost analysis to estimate the costs and benefits for each additional unit of recycled materials, and to obtain the optimum level of recycling which maximized public welfare. Benefits were assessed in terms of landfill and waste collection costs avoided through recycling, as well as other positive externalities. Similarly, costs were evaluated in

terms of expenditure for collection of waste and sorting of recyclables. The quantity of recycled goods sold from such waste was deducted and entered the analysis as a benefit. The study ultimately assessed the overall net benefit of recycling to New Zealand at between 2.9 million and 3.7 million metric tons of recyclables[22] in 2007.

Another study by CM Consulting (2007) measured the benefits and costs of composting source-separated organic waste in the Niagara region of Canada. The study applied a full-cost accounting methodology to assess 'true costs' of composting, landfill operations and energy-from-waste operations, by estimating the difference between net operational costs and environmental cost benefit. In this application, environmental benefit or cost was measured as the monetized value of various pollutants plus the avoided pollutants which would be derived from the use of finished compost instead of synthetic fertilizers. This study estimated a true cost or net benefit of composting to range from US$ -15.76 per metric ton for leaf and yard brush, to US$ 142.72 per metric ton for energy-from-waste operations.

Other studies also provided broad guidelines for conducting benefit-cost analyses. These included the "Jasper Guidelines"[23] prepared for policy analysis by the European Investment Bank, as well as the United States Environmental Protection Agency (EPA) Waste Reduction (WARM) Model. Beede and Bloom (1995) also identified key considerations for assessing benefits and costs of municipal solid waste management options, and highlighted the following key areas:

- Relative costs of labour and other production factors.
- Composition and physical characteristics of municipal solid waste.
- Efficiency of scale of operations.
- Non-pecuniary costs and benefits.

Given the paucity of data on municipal solid waste management in the Caribbean, it was not possible to assess many aspects of the above areas. The studies did, however, guide the orientation of the benefit-cost analysis, based on the following key considerations:

Limited recycling in the Caribbean

While there is evidence of numerous recycling initiatives in the Caribbean, the practice is not well developed. Over the past decade, however, a burgeoning trade in scrap metals recovered from landfills has evolved in many countries, in response to an overall upward trend in global prices for virgin metals. Still, other efforts to recycle plastics, paper, cardboard, and glass have been largely small-scale and sporadic, reflecting the highly volatile nature of such markets, as well as the overall low volumes of recyclable materials which can be extracted at national level in the Caribbean. Indeed, the Caribbean Environmental Health Institute (CEHI, 2011) has noted that the absence of a de facto market for recyclables is the one of the main constraints to the development of recycling in the Caribbean. Since data for incorporating recycling in any analysis were not available, recycling was not included in the benefit-cost analysis.

Waste disposal options limited to land filling operations

Landfills are acknowledged to be the most widely-used municipal waste-disposal method in the Caribbean. Their high scale efficiency allows them to be used for the diverse range of population sizes typical to the Caribbean. Additionally, other waste-management strategies — such as waste-to-energy, composting and incineration — have, so far, had little or no application in the Caribbean. Landfill operations are therefore the only disposal method considered in the present benefit-cost analysis

[22] Note that the COVEC study did not value these net benefits across the various groups of recycled materials.

[23] JASPERS is the Joint Assistance to Support Projects in European RegionS, and is a major policy initiative of the European Union (EU). This initiative is designed for 12 EU member States in order to assist them in preparing better project proposals for EU Fund financing.

Waste management is key to reducing public health risks

Efficient solid waste management is a critical factor in mitigating public health risks. These include cholera and typhoid from contamination of food and water, dengue fever caused by mosquitoes bred in improperly-disposed containers, and leptospirosis from rodent infestations caused by poorly-managed municipal waste collection, treatment and disposal. The analysis therefore treats waste management as a social benefit since it contributes to reducing these and other public health risks. Benefits to public health are entered into the analysis as the avoided value of a statistical life lost, plus the avoided productivity losses due to morbidity from selected public health diseases.

Waste management maintains natural aesthetics

Waste management also contributes to the maintenance of a clean natural environment, which is not only important to Caribbean residents, but also to visitors. Given the importance of the tourism industry to the Caribbean, municipal solid waste management is seen as adding a premium to the visitor experience. Such a premium is assessed in the benefit-cost analysis in terms of visitors' willingness to pay for a clean destination.

Waste management creates direct economic benefits

Municipal waste management activities are carried out through local government agencies that either employ workers directly to undertake this function, or operate through the contracting of private entities. This function therefore creates direct economic activity through the payment of wages, the purchase and/or leasing of capital, and the purchase of other material inputs. In this analysis, direct economic benefits are incorporated as part of the operational costs of municipal solid waste management agencies.

Although empirical experience suggests that other considerations are likely to be important in assessing the benefits and costs of municipal solid waste management, both the lack of data as well as the difficulty of conceptually incorporating and evaluating such factors have precluded them from the analysis. Two such factors are the contribution of municipal waste management to mitigating urban flooding, and the benefits of municipal waste management to the preservation of biodiversity.

In the case of urban flooding, the complexity of hydrological, weather and physical planning and socio-cultural behaviour makes it well-nigh impossible to disaggregate flood-related benefits or costs that are exclusive to municipal solid waste management. Moreover, flooding events in the Caribbean are usually associated with extreme weather events, with overwhelming physical damage and losses which may not be avoided by even the most efficient regime of solid waste management. Still, good solid waste management is an important contributor to flood mitigation since it reduces the likelihood of local drainage systems being clogged by litter.

With respect to biodiversity, the overall ecology related to the impact of point and non-point sources of pollution (including municipal solid waste), the differential impacts of waste on various species, and the variation in possible impacts due to differing ecosystems (terrestrial, marine) also make it impossible to account for these effects in terms of benefits and costs in the analysis.

The tangible benefits and costs of municipal solid waste management applied in the present study are presented in table 3.

TABLE 3
BENEFITS AND COSTS FOR CASE STUDY ANALYSIS[a]

Benefits[a]	Costs
Avoided public health impacts	Annual operating costs for national solid waste management
Preserved aesthetic values	Opportunity costs of land used for landfill sites
Direct economic benefits	

Source: Author

[a]. Based on the above, benefit cost analysis for the two case countries are elaborated below.

B. Case study – Saint Lucia

Saint Lucia forms part of the southern archipelago of the Caribbean chain of islands, and is located north of Trinidad and Tobago, with coordinates 13° 53′ North, and 60° 58′ West. It is one of the larger islands of the southern group known as the Windward Islands, and has a land area of 619 square kilometres. In 2005, the island had a land use profile of 6.45% arable land, with 22.6% permanent crops and 70.8% other crops (Wikipedia, 2011). In terms of natural resources, the island has extensive rainforests, numerous sandy beaches, minerals (pumice), and, on account of its relatively recent volcanic history, mineral springs and geothermal potential. As noted by CEHI (2011), the main environmental challenges which currently confront Saint Lucia are deforestation, ecosystem degradation and soil erosion, the effects of which are especially evident in the northern areas of the island.

Until the early 1990s, Saint Lucia was one of the main banana exporters of the Windward Islands. Over the past two decades, however, tourism has emerged as the principal economic driver, contributing as much as 37.4% to GDP in 2009 (ECLAC, 2010). This figure represents a decline from 2008, after the tourism sector showed a steady increase from 2005. Tourism also contributed as much as 37.1% to national employment in 2009 (ECLAC, 2010).

The management of municipal solid waste is undertaken by the Saint Lucia Solid Waste Management Authority (SLSWMA) which was established by an Act of Parliament in 1996. This agency has the mandate to provide coordinated and integrated systems for the collection, treatment, recycling and disposal of solid waste, including hazardous waste, and to establish and manage sanitary landfills (SLSWMA, 2008). The Authority also has responsibility for managing biomedical waste, as defined under relevant regulations.

In discharging its mandate, SLSWMA manages an integrated waste management system which comprises one engineered sanitary landfill located at Deglos in the north of the island, and an upgraded disposal site located at Vieux Fort in the south. The Deglos sanitary landfill is a nine-hectare purpose-engineered facility with clay lining, piping and two leachate ponds to prevent contamination of groundwater. It is also equipped with a weigh bridge, autoclave and tire shredder. Waste collection services are provided for both kerb and communal bins, and are organized into eleven collection zones, which are serviced by private contractors, thereby providing collection to 100% of the island. The disposal site at Vieux Fort comprises 7.4 hectares, and serves most of the communities in the south of Saint Lucia.

TABLE 4
TONNAGE OF WASTE DISPOSAL - SAINT LUCIA

Year	Waste quantity (tons)		
	Deglos sanitary landfill	Veux Fort waste disposal facility	TOTAL
2004/2005	49 885	23 130	73 015
2005/2006	59 426	22 191	81 617
2006/2007	58 663	20 173	78 836
2007/2008	64 691	19 836	84 527

Source: Saint Lucia Solid Waste Management Authority.

Saint Lucia generated an estimated 80,470 metric tons of waste in 2008 (Simmons, 2011) with an approximate growth rate of 0.62% per annum since 2004. This translates to a daily per capita waste-generation rate of 1.44 kg. Table 4 summarizes growth trends for waste disposal at the country's two landfills since 2004. Based on a 2008 waste characterization study, the major components of municipal waste generated were organics (45%), plastics (22%) and paper and paperboard (10%) (SLSWMA, 2008).

The Saint Lucia Solid Waste Management Authority also promotes waste reduction initiatives by supporting the recycling of lead batteries, scrap metal, PET bottles, corrugated cardboard and paper. This programme is supported by a vigorous public education campaign, as well as through strong links with community-based organizations, the commercial sector, and other stakeholders (CEHI, 2011).

There is a strong relationship between solid waste management and public health. The main public health issues associated with solid waste in Saint Lucia include gastroenteritis and dengue fever. Since 2010, leptospirosis has also emerged as a pubic health concern. The maintenance of a clean and pleasing environment is a key strategy for avoiding many of the public health costs that are likely to arise from a deficient solid waste management regime. Moreover, given the high level of dependence on tourism in Saint Lucia, a clean environment is important for attracting visitors which, in turn, contributes to tourism sector earnings.

Saint Lucia is well served in the number of laws and regulations that support municipal solid waste management (table 5).

TABLE 5
POLICIES, LAWS AND REGULATIONS GOVERNING SOLID WASTE MANAGEMENT IN SAINT LUCIA

Policies, Laws and Regulations	
Solid Waste Management Authority Act	Coordinates and integrates systems for collection, treatment, recycling and disposal of waste. Manages, regulates, controls and treats waste independently or in conjunction with private companies
Waste management (biomedical waste) (Transport, treatment and disposal)	Provides guidelines for proper management of biomedical waste: creates an operational plan for proper packaging, storage and on-site disposal
Castries Corporation act	Regulates solid waste practices of persons in the City of Castries, enforces its laws, and makes contracts for the collection and disposal of waste
Town and Village Act	Charges Towns, Districts and Rural Councils with the responsibility of cleanliness of streets, and public places or places of public resort

(continued)

Table 5 (concluded)

Litter Act	The Minister of Health plays an enforcing role; issues licences to operations for collection and disposal of waste and location of disposal sites
Works and roads	Minister of Communication, Works and Public Utilities holds limited powers with regard to waste management. Under this act, the Minister is given powers to clear verges and drains
Public Health Act	The Public Health Act of 1975 gives the Environmental Health Department (EHD) of the Ministry of Health responsibility for the control of public health issues such as water, solid and liquid waste, and food. This Ministry, as well as the Environmental Unit of the Ministry of Planning, also monitors solid waste management systems and operations

Source: Simmons and Associates 2011.

The current solid waste management system in Saint Lucia reflects the results of a medium-term development initiative implemented in the Eastern Caribbean States. Known as the OECS Solid and Ship-Generated Waste Management Project (OECS SWMP), this World Bank -funded initiative was implemented over a period of eight years from 1995-2003. Its main objective was to "reduce public health risks and protect the environmental integrity of the islands and their coastal and marine systems." (World Bank, 2003). The project focused on controlling terrestrial pollution in an effort to preserve the marine environment. It also undertook improvements in domestic waste facilities in order to ensure compliance to the Special Area designation of the Caribbean Sea for MARPOL 73/78 (World Bank, 2003). The project was implemented in six OECS countries: Antigua and Barbuda, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia, and Saint Vincent and the Grenadines. The following general outcomes were achieved to varying degrees in each of the project countries:

- The establishment of semi-autonomous solid waste management entities (SWMEs)
- Increased coverage and improved quality of land-based solid waste management services (collection, transport and disposal)
- Enhanced public awareness of solid waste management issues, resulting in behavioural changes
- Improved institutional arrangements with functioning systems to help each country manage and dispose effectively of waste generated by ships and leisure craft
- The OECS SWMP was also instrumental in the establishment of 7 new sanitary landfills,24 the upgrading of 6 existing ones, and targeting 22 others for closure (CSD, 1998)

1. Benefit-cost analysis

Estimating benefits

In the case of avoided public health impacts, Kimani (2007), in a study of solid waste disposal at the Dandora municipal waste dump in Nairobi, identified the main public health effects to be bacterial infections which caused respiratory anomalies, abdominal and intestinal problems, skin disorders, eye infections and dental disorders. Data from the Caribbean Epidemiology Centre (CAREC, 2008) also revealed the main public health risks for Saint Lucia to be consistent with these broad effects, with the main waste-related impacts being gastroenteritis, dengue fever[25] and leptospirosis.[26] While morbidity

[24] Sanitary landfills are sites where waste is isolated from the environment until it is safe

[25] Although dengue fever is not a bacterial infection, it is related to waste management since its vector – the *Aedes* mosquito - thrives under conditions of poor municipal waste management.

data for Saint Lucia also showed a significant occurrence of acute respiratory infections, these were mainly related to airborne viral infections such as influenzae, and not to those diseases caused by bacterial infections as identified in the Kimani study.[27] Moreover, it would be difficult to link such infections to any waste-management deficiencies in Saint Lucia and, as such, respiratory infections were excluded from the analysis.

In order to set a value for the avoided public health impacts, 2009 estimates for the value of a statistical life (VSL) time series for Saint Lucia, as generated by ECLAC (2011), were used to assess annual per capita morbidity and mortality for dengue fever and gastroenteritis. Since these figures were unavailable for leptospirosis, this disease was excluded from the analysis. Additionally, examination of the incidence of diseases since 1980 showed a 55% decline in reported cases of gastroenteritis after 2003, the year in which the Deglos sanitary landfill was operationalized. It was therefore assumed that enhanced solid waste management resulted in the avoidance of at least 55% of this public health threat. VSL estimates were then multiplied by 55% of the total number of reported incidents in order to estimate the avoided public health damage for gastroenteritis. A similar approach was applied for dengue fever and the figures summed to obtain a total benefits stream.

The next area of benefits assessed was the aesthetic value of Saint Lucia which was preserved by solid waste management activities. This was measured in terms of the value which both local residents and visitors ascribed to having a clean, aesthetically-pleasing space for living and recreation. This assessment was based on willingness to pay for the preservation of the environment. This approach is not inconsistent with the findings of Mercado and Lassoie (2002), who observed that up to 91% of visitors to the Punta-Cana resort area of the Dominican Republic rated clean beaches and clean water as important elements which drew them to the destination. It was assumed that a similar dynamic operated to attract both cruise and stop-over visitors to Saint Lucia. Allport and Epperson (2003) estimated willingness to pay for small business persons involved in ecotourism activities for the Windward Islands to be US$ 442.80 per year, while Edwards and others (2009) estimated willingness to pay per visitor for coastal preservation in Jamaica at US$ 128.00. These studies reflected willingness to pay values for businesses and visitors. Beharry-Borg and Scarpa (2010) estimated willingness to pay values for coastal environmental quality to approximately US$ 2.22 for local residents[28] in Tobago. The findings of these two studies corroborated the conclusion by Mercado and Lassoie (2002) that local residents tended to be more tolerant of lower environmental quality compared to international visitors, and were therefore less willing to pay for the preservation of environmental quality.

These findings were used to inform the estimation of marginal aesthetic benefits from solid waste management in Saint Lucia by applying the following assumptions:

- Municipal waste management contributed only partially towards the enhancement and maintenance of physical aesthetics in Saint Lucia, and a large share of the island remained in a continuously pristine state because of the absence of built development. A contribution weight factor of 30% was applied.
- Since solid waste coverage only reached 90% of the resident population, benefits for this proportion of the population were estimated.
- All visitors to Saint Lucia benefited from the marginal aesthetic value (30%) generated by solid waste management activities.

[26] Leptospirosis had not previously been reported in Saint Lucia. However, there has been an increase in reporting of this disease in the country subsequent to the passage of Hurricane Tomas in 2010.

[27] These included pharyngitis, laryngitis, rhinitis, chronic bronchitis, and asthma.

[28] In their study, Beharry-Borg and Scarpa sought to assess willingness to pay values for both snorkellers and non-snorkellers in Tobago. The demographic partitioning of the data revealed a high correlation between local residency and non-snorkelling, leading them to presume that most non-snorkellers were locals.

Aesthetic values from municipal solid waste management were therefore estimated by multiplying willingness to pay values for locals and visitors by the relevant proportion of the population for each category, to obtain a total estimated benefit per year.

It was not possible to separate estimates of direct economic benefits, since the overall reported cost per unit for waste collection included wages paid as well as supplies purchased. It was therefore assumed that these benefits were transferred to the economy, and were reflected in the operational costs of the Saint Lucia Solid Waste Management Authority.

Estimating costs

Cost streams for the present analysis were derived from the annual operating cost of municipal waste collection in Saint Lucia, as well as the opportunity cost of land used in landfill operations. Operating cost was derived from the product of the average collection and disposal costs per ton of municipal waste handled by the Saint Lucia Solid Waste Management Authority and the total annual quantity of waste handled. Assessment of the opportunity cost of land used in landfill operations was based on the real estate land rental value[29] of land located close to existing landfill sites.

Results of benefit-cost analysis - Saint Lucia

The total benefits and costs, breakeven analysis, and cumulated net benefits and costs were estimated for a period of five years using a discount rate of 8% per year. The choice of discount rate was based on guidelines offered by Zhuang and others (2007) who suggested that social discount rates for developing countries should range between 8% and15%. This range was deemed to best reflect differences in economic structure, capital scarcity, and stage of financial development and efficiency of capital in developing markets relative to developed economies. In the case of Saint Lucia, the lower bound for this range was applied to the analysis. The estimation of the full benefits and costs for Saint Lucia are presented in the appendix. The results of the benefit-cost analysis are shown in table 6.

The benefit-cost ratio ranged from 9.57 to 10.90 over the five-year period,. Annual total benefits ranged from a minimum of US$ 27.4 million to US$ 36.6 million, of which preserved aesthetic values ranged from US$ 25.5 million to US$ 35.3 per year, over the five year period. By these estimates, the share of aesthetic values amounted to approximately 94% of total benefits. Cumulative benefits over the five-year period amounted to approximately US$ 159 million, representing the overall social benefit to Saint Lucia during five years of solid waste management activities.

At the same time, total costs were assessed at between US$ 2.9 million and US$ 3.2 million per year, with the larger share of costs ranging between US$ 1.8 million and US$ 1.9 million per year representing the operational cost of solid waste management activities. Operating cost was 65% of total cost, while cumulative cost amounted to US$ 15.1 million over the period.

The cumulative net benefit was estimated at US$ 114.8 million for the period of analysis, suggesting that, overall, investment in municipal solid waste management yields a substantial social benefit to Saint Lucia.

[29] Value estimates obtained from consultation with local realtors.

TABLE 6
RESULTS OF BENEFIT-COST ANALYSIS – SOLID WASTE MANAGEMENT: SAINT LUCIA
(US$)

	Year 1	Year 2	Year 3	Year 4	Year 5
			US$		
Tangible benefits					
Avoided public health damage/risks	3 006 066.95	3 209 142.3	1 212 574.55	1 335 283.4	900 944.45
Aesthetic values preserved from SWM	27 449 088.45	25 521 929.33	34 575 634.21	35 251 150.29	26 544 586.36
Total Benefits	30 455 155.4	28 731 071.63	35 788 208.76	36 586 433.69	27 445 530.81
Tangible Costs					
Operational costs for SWM activities	2 150 764.81	1 914 734.82	1 832 146.24	1 939 885.47	1 933 067.03
Opportunity costs - land filling	1 059 168.74	1 059 168.74	1 059 168.74	1 059 168.74	1 059 168.74
Amortized capitalization costs	0.00	0.00	0.00	0.00	0.00
Total costs	3 209 933.55	2 973 903.56	2 891 314.98	2 999 054.21	2 992 235.77
Break even analysis (benefits-costs)	27 245 221.85	25 757 168.06	32 896 893.78	33 587 379.47	24 453 295.05
Cumulative benefits		59 186 227.03	94 974 435.79	131 560 869.47	159 006 400.29
Cumulative costs		6 183 837.11	9 075 152.09	12 074 206.31	15 066 442.08
Benefit-cost ratio		9.57	10.47	10.90	10.55
Net present value of benefits (8%)	28 199 217.96	24 632 263.06	28 409 833.96	26 892 120.97	18 678 967.11
Net present value of costs (8%)	2 972 160.69	2 549 642.97	2 295 219.05	2 204 394.38	2 036 465.39
Cumulative net benefits		52 831 481.02	81 241 314.98	108 133 435.95	126 812 403.05
Cumulative net costs		5 521 803.67	7 817 022.72	10 021 417.09	12 057 882.48
Benefit-cost ratio		9.60	10.40	10.80	10.50
Net benefits/costs	25 227 057.27	22 082 620.08	26 114 614.91	24 687 726.59	16 642 501.72
Cumulative net benefits/costs	25 227 057.27	47 309 677.35	73 424 292.26	98 112 018.85	114 754 520.57
Interest rate (percentage)	0.08	0.08	0.08	0.08	0.08

SWM =Solid Waste Management.

C. Case study – Trinidad and Tobago

Trinidad and Tobago is a twin-island State which lies on the southern tip of the Caribbean archipelago, north-east of Venezuela, with coordinates 11° 00′ North, and 61° 00′ West. The total land area of both islands is 5,128 square kilometres, of which Tobago, the smaller island, occupies approximately 300 square kilometres. Only 14.62% of the total land area is considered arable, with 9% currently under permanent crops and the remainder being other vegetation. Petroleum, natural gas and asphalt are the principal natural resources in Trinidad, while Tobago boasts substantial touristic resources in the form of fine beaches, reefs and rainforests.

Strong economic growth, accompanied by extensive built development over the past decade has resulted in significant environmental challenges for Trinidad and Tobago. Such challenges include

water pollution from agricultural chemicals, industrial waste and raw sewage, oil pollution of beaches, deforestation, and soil erosion (Simmons, 2011).

The energy sector is the main economic driver in Trinidad and Tobago, with petroleum contributing roughly 40% of GDP during the period 2005 to 2009 (ECLAC, 2010). The shares of GDP for construction and manufacturing were also significant, at 7.8% and 8.1%, respectively, during this period. The country serves as a major supplier of manufactured food, beverages, and cement to the rest of the Caribbean.

The Trinidad and Tobago Solid Waste Management Company Limited (SWMCOL) was the first waste management operation in the Caribbean. The company was established in 1980 as a State agency to support the development of solid waste support services in Trinidad and Tobago. SWMCOL, the Municipal Corporations of the Ministry of Local Government in Trinidad, and the Tobago House of Assembly in Tobago, are the main public agencies involved in solid waste management in the country. Waste collection is undertaken mainly by private contractors, and disposal takes place in four landfill sites – three in Trinidad, and one in Tobago. The largest of these is the Beetham landfill located in north-west Trinidad, which is 61 hectares in extent. The Guanapo landfill, significantly smaller at 8 hectares, is located in north-east Trinidad, while the Forres Park landfill (7 hectares) is located in central Trinidad. Tobago is served by the Studley Park landfill which covers 6.25 hectares on the eastern-central coast of the island. Both Forres Park and Studley Park are engineered landfills, while the others were upgraded to enhance the waste-disposal process. All of these landfill developments were established during the early 1980s and, consequently, these sites are now nearing, or have exceeded, their engineered lifespan and are now scheduled for closure.

Apart from public agencies, there is also private involvement in waste collection and recovery, especially for glass, paper, metals, e-waste and plastics (Simmons, 2011).

Trinidad and Tobago was estimated to generate 700,000 tons of waste in 2010 (SWMCOL, 2011) or a daily equivalent of 1,917 tons. While recent data are unavailable, figures for 2005 indicated the per capita waste generation in Trinidad and Tobago to be about 2.2 kilograms per day, and total daily waste production to be 1,548 tons (CSO, 2008) . These figures suggest an increase in daily waste generation of 24% between 2005 and 2010, consistent with the strong rate of economic growth, consumption and urbanization in Trinidad and Tobago during this period.

A 2010 waste characterization study revealed organics (27%), paper (19%), plastics (19%) and glass (10%) to have the largest shares in the waste stream. These figures are summarized in table 7.

TABLE 7
SOLID WASTE CHARACTERIZATION FOR TRINIDAD AND TOBAGO, 2010

Waste category	Percentage
Organics	27
Paper	19
Old corrugated cardboard	4
Plastics	19
Textiles	8
Beverage containers	1
Household hazardous	5
Construction and demolition	1
Metals (ferrous)	2
Metals (non-ferrous)	1
Glass	10
Other	3

Source: SWMCOL 2010.

There is currently no consolidated solid waste management strategy for Trinidad and Tobago, although several initiatives have been undertaken recently to strengthen the strategic framework for solid waste management in the country. Among these are the National Environmental Policy and the municipal policy framework for solid waste management. A draft national strategic plan was also recently completed by the Ministry of Local Government, and draft waste management rules prepared. Table 8 provides a summary of the policies, laws and regulations that govern solid waste management in Trinidad and Tobago.

TABLE 8
POLICIES, LAWS AND REGULATIONS RELATED TO SOLID WASTE MANAGEMENT IN TRINIDAD AND TOBAGO

Polices. laws and regulations	
Solid Waste Management Company (SWMCOL)	Manages the three major landfill sites: Beetham, Forres Park and Guanapo. The Tobago House of Assembly operates the Tobago site at Studley Park
National Environmental Policy and Municipal Policy Framework for Solid Waste	Guidance for the development of a comprehensive policy for the country
Litter Control Act, 1973	Empowers local authorities to take steps to prevent or where necessary remediate the effects of littering in all public spaces or in private spaces where littering may be deemed a public-health risk
Public Health Act of 1950 and regulations	Provides local authorities with the powers and responsibility of enforcement of all regulations to protect public health
Municipal Corporations Act, 1990	Governs the municipal corporations, mandates the municipals to dispose of garbage, to be responsible for the development and maintenance of sanitary landfills, the abatement of public nuisances
The Environmental Management Act	Mandates the Environmental Management Authority to develop and implement a programme of management for waste, and to provide the development of rules to address waste handling and the disposal of hazardous waste
Other related legislation	
Pesticides and Toxic Chemicals Act; Occupational Safety and Health Act; A Code of Practice for Biomedical Waste Management	

Source: Simmons and Associates 2011.

As in all countries, solid waste management holds implications for national public health. In the case of Trinidad and Tobago, the main public health issues associated with solid waste are gastroenteritis, dengue fever and leptospirosis.

The Government of Trinidad and Tobago has embarked on the development of a waste management/resource use policy which will explore the possibility of excluding organics from the waste stream as well as shredding tyres for reuse in the cement industry. Additionally, there has been a recent Government initiative to implement a deposit refund system for the recycling of PET bottles, which is currently a major waste management challenge in the country.

1. Benefit-cost analysis

Estimating benefits

The same basic assumptions applied to Saint Lucia were employed (with minor adjustments) in estimating the benefits to Trinidad and Tobago of municipal solid waste management. The key assumptions for the Trinidad and Tobago analysis were the following:

- Given the relatively higher per capita generation of solid waste in Trinidad and Tobago, as well as the higher intensity of built development, municipal waste management contributed a higher weight towards the enhancement and maintenance of physical aesthetics in Trinidad and Tobago. A contribution weight factor of 45% was applied.

- Solid waste coverage reached 100% of the resident population. Hence benefits for the total population were estimated.
- All visitors to Trinidad and Tobago benefited from the marginal aesthetic value (45%) generated by solid waste management activities.
- In the case of Trinidad and Tobago, a mean willingness to pay for recreational services by visitors was set at US$ 9.30, which represented the upper bound estimate for such services (WRI/Burke, 2008). Furthermore, willingness to pay value for environmental quality was set at US$ 1.50 for local residents, based on the findings of Beharry-Borg and Scarpa (2010).
- The availability of data on leptospirosis incidence made it possible to include this disease in the estimation of benefits from avoided public heath damage due to solid waste management.

Estimating costs

Similar to the case of Saint Lucia, the estimation of costs was based on the operational cost of national waste management, as well as the opportunity cost of land used for landfill sites.

The cost of waste handling was estimated at TT$ 226 million (US$ 35.9 million) in 2010 (Simmons, 2011). The total volume of waste collected in Trinidad and Tobago was estimated at 700,000 tons in 2010 (SWMCOL, 2011). This gives an average waste handling cost per metric ton of US$ 51.25. Adjusting this figure for inflation, the cost of waste handling in Trinidad and Tobago was estimated to range from US$ 45.57 to US$ 63.83 per metric ton over the period of analysis – 2000 to 2004. These figures were used to estimate total operating costs in the benefit-cost analysis.

The opportunity cost of land used for land filling in Trinidad and Tobago was estimated to be US$ 0.24 per square foot. This was based on valuations of rural land in Trinidad and Tobago.

Finally, in contrast to the Saint Lucia case, a discount rate of 6% was used in the analysis to reflect the relatively lower scarcity of capital in Trinidad and Tobago during the period of analysis. The results of the benefit-cost analysis are presented in table 9.

Results of benefit cost analysis – Trinidad and Tobago

In the case of Trinidad and Tobago, the benefit-cost ratio ranged from 0.97 to 1.24 over the five-year period of analysis. The minimum annual total benefits were US$ 25.6 million while the maximum was US$ 31.9 million. Unlike Saint Lucia, avoided public health impacts comprised the larger share of total benefits (90%) and ranged from US$ 22.7 million to US$ 29.2 million per year over the five-year period. Hence, solid waste management contributed larger social benefits to Trinidad and Tobago in terms of public health, but relatively less in terms of preserving aesthetic values. Cumulative benefits for the country amounted to roughly US$ 143.1 over the five-year period of analysis.

Trinidad and Tobago managed its municipal solid waste at far greater cost per metric ton than Saint Lucia. Total costs were estimated at between US$ 23.2 million and US$ 39.3 million per year, with 93% of costs being for operations, ranging from a minimum of US$ 21.1 million to a maximum of US$ 37.2 million per year during the five-year period. Overall, cumulative costs amounted to US$ 147.7 million over the period of analysis.

Significantly, cumulative net benefits for Trinidad and Tobago were negative, assessed at −US$ 6.8 million over the period. This suggested that the country generated less social benefits relative to the cost of undertaking solid waste management during the assessment period.

Additionally, the estimated benefit-cost ratios were marginally greater than 1 for four years, and less than 1 in year five, indicating that the social benefit from investment in solid waste management was not substantial relative to expenditure, and was even less than the social cost in the final year of the analysis..

TABLE 9
RESULTS OF BENEFIT-COST ANALYSIS – SOLID WASTE MANAGEMENT: TRINIDAD AND TOBAGO

	Year 1	Year 2	Year 3	Year 4	Year 5
			US$		
Tangible benefits					
Avoided public health damage/risks	22 675 348.00	29 181 196.10	25 023 729.10	24 697 465.10	27 254 799.1
Aesthetic values preserved from SWM	2 955 561.75	2 802 673.98	2 720 333.16	2 810 006.91	2 950 503.3
Total benefits	25 630 909.75	31 983 870.08	27 744 062.26	27 507 472.01	30 205 302.4
Tangible costs					
Operational costs for SWM activities	21 240 906.12	21 145 596.50	25 739 558.92	31 730 633.28	37 219 209.17
Opportunity costs - land filling	2 124 795.51	2 124 795.51	2 124 795.51	2 124 795.51	2 124 795.51
Total costs	23 365 701.63	23 270 392.01	27 864 354.43	33 855 428.79	39 344 004.68
Break even analysis (benefits-costs)	2 265 208.13	8 713 478.08	(120 292.17)	(6347956.77)	(9138702.28)
Cumulative benefits		57 614 779.83	85 358 842.09	112 866 314.1	143 071 616.5
Cumulative costs		46 636 093.63	74 500 448.06	108 355 876.84	147 699 881.52
Benefit cost ratio		1.24	1.15	1.04	0.97
Net present value of benefits (6%)	24 180 103.54	28 465 530.51	23 294 449.66	21 788 494.27	22 571 159.08
Net present value of costs (6%)	22 043 114.74	20 710 566.04	23 395 449.28	26 816 670.61	29 400 129.05
Cumulative net benefits		52 645 634.05	75 940 083.71	97 728 577.98	120 299 737.06
Cumulative net costs		42 753 680.78	66 149 130.07	92 965 800.67	122365,929.72
Benefit-cost ratio		1.2	1.1	1.1	1
		1	1	1	1
Net benefits/costs	2 136 988.80	7 754 964.47	(100 999.62)	(5028176.34)	(6 828 969.96)
Cumulative net benefits/costs	2 136 988.80	9 891 953.26	9 790 953.64	4 762 777.31	(2066192.66)
Notes: Interest Rate		0.06	0.06	0.06	0.06

Source: Author's calculations.

Additionally, the estimated benefit cost ratios were marginally greater than 1 for four years, and less than 1 in year five, indicating that social benefits from investment in solid waste management are not substantial relative to expenditure, and were even *less* than costs in the final year of the analysis.

V. Improving solid waste management systems in the Caribbean

Although a comparison of the two case study countries points to relative success for Saint Lucia in terms of social benefits, the overall municipal solid waste management regime on the Caribbean still offers opportunities for improvement. The present study identifies the following as a critical – yet by no means exhaustive – list of strategies for enhancing waste management operations in the Caribbean.

Implementing fully integrated solid waste management systems

The aim of integrated waste management is to minimize, to the greatest extent possible, the negative impacts associated with the collection and disposal of solid waste. Integrated approaches, therefore, are driven by strong waste-minimization strategies that are backed by robust monitoring, collection, transportation, processing and disposal systems. The approach to integrated solid waste management is based on the classical waste management hierarchy, which places waste reduction as the most preferred option of solid waste management, with waste disposal being the least desirable (figure 1). Observation suggests that the current Caribbean solid waste management strategies are focused on the lower levels of the waste management hierarchy. An integrated solid waste management approach would shift the strategies to the higher levels. This should be supported by an extensive public-awareness programme.

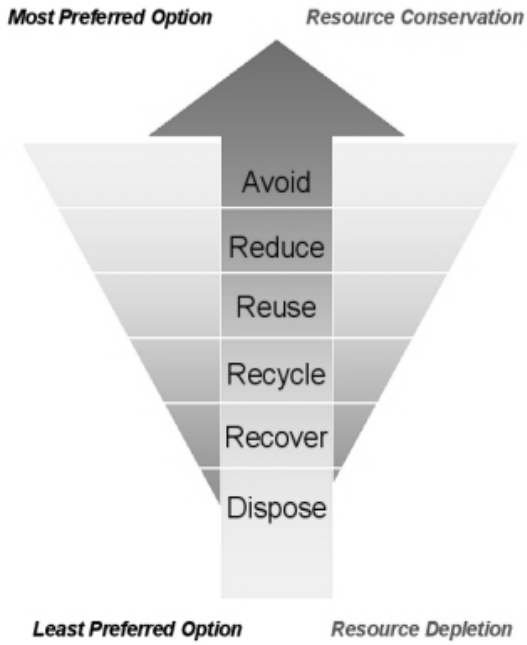
Promoting of national composting

Given that the most dominant component of the waste streams in the Caribbean is organic waste, waste reduction through a process of composting should be a key strategic approach to Caribbean waste management. One option that could be explored is the development of national and domestic composting programmes with supporting incentives to encourage reduced levels of organic waste landfills. This may be achieved through the promotion of national and community composting programmes. This is especially important since there is a real scarcity of land for landfill sites in the small islands of the Caribbean. Composting has broader social benefits, as noted by the Intergovernmental Panel on Climate Change (IPCC). Composting yard waste yields comparatively the same emissions as landfill operations, whereas food waste composting yields far less emissions than landfill operations.

Promotion of recycling

The promotion of recycling as a waste-minimization strategy continues to be widely promoted in the Caribbean. Current empirical evidence suggests some potential for the development of this activity, although market volatility, limited scale of operation and the absence of an enabling policy framework have restricted its full development. The main recyclables in the Caribbean include metals, plastics and paper. However, small domestic markets and high transportation costs impose scale limitations on the recycling process. Consideration should be given to a Caribbean trade in recyclables which would serve to increase volumes, and foster specialization among recycling traders. Formalization of policy instruments, such as deposit refund systems and other fiscal incentives, would provide significant impetus for the development of recycling in the Caribbean.

FIGURE 1
SOLID WASTE MANAGEMENT HIERARCHY



Source: http://www.greengc.com.au/get-informed-3/what-is-waste

Review of fee structures for municipal solid waste Management

In most Caribbean countries, municipal solid waste collection is undertaken at zero cost to households, with the cost of waste services typically being financed through a budgetary allocation from the central government. The absence of specific disposal fees to the household provides no incentive to reduce generated waste. While specific tipping fees may be levied to commercial and, in some instances, institutional waste generators, the application of a regime of waste disposal fees to households should be considered, since it will serve to reduce household waste generation, foster greater reuse of recyclables, and generate income to municipal waste haulers. This recommendation is, however, made with the caveat that an a priori comprehensive assessment of the elasticity of waste fees on households be undertaken since, in the absence of efficient collection and regulation, imposed fees may lead to increased illegal dumping and littering.

Strengthening institutional and regulatory frameworks for municipal solid waste management

Solid waste management in the Caribbean is substantially constrained by weak institutional coordination and poor regulatory framework. Limited funding and insufficient human resources often weaken the capacity of municipal agencies to implement the capital and management systems necessary to guarantee an efficient waste management service. This situation is exacerbated by the absence a fee-collection regime to provide a measure of cost recovery, making waste collection agencies almost totally dependent on central government to fund their operations. Many agencies function under a highly-dispersed legislative jurisdiction, with key enforcement, policy and operational guidelines being distributed across several public agencies, including Ministries of Health, Environment, Local Government, Works and Infrastructure, Finance and even Municipal Corporations. These arrangements often stymie the efficacy of waste-collection services, and need to be streamlined in order to enhance the efficiency of waste management operations. A particular deficiency, one which warrants immediate attention, is the collection of solid waste data critical to the future planning and development of solid waste management systems.

Promotion of public-private partnerships for solid waste management

Given the pervasive nature of both the benefits and costs of solid waste management to society, efficient waste management in the Caribbean would also be improved through stronger public-private partnerships. To date, such partnerships exist largely to the extent that public agencies enter into contracts with private entities to provide collection and disposal services. However, further opportunities exist in areas such as the development of recycling markets, public education and awareness programmes, the development and deployment of appropriate technologies, training of human resources, and the investment in waste-collection and -handling infrastructure. The promotion of public private partnerships should, therefore, be further explored for the future development of municipal solid waste management systems in the Caribbean.

VI. Limitations of the research

The present study sought to assess the benefits and costs associated with municipal solid waste management in the Caribbean. Several important limitations should be noted in the context and conclusions which may be drawn from the research.

Without doubt, the absence of relevant data was a major drawback in undertaking the analysis. In many instances, disaggregated data were not available to inform aspects such waste collection operational costs, capitalization, assessment of land values, recycling, and the direct and marginal economic impacts of solid waste management activities. The role of waste pickers in solid waste management, for example, and their contribution to the economy through recycling activities, remains unquantified. As a consequence, the analysis was undertaken at an aggregate level, and did not allow for any partial analyses of benefits and costs.

The analysis was also constrained by the absence of specific studies which would have supported the assessment. For instance, although it is recognized that municipal solid waste management is a key contributor to mitigating urban flooding, no studies were available to guide the incorporation and calibration of this factor into the benefit-cost analysis. Neither were there studies assessing the impact of waste management activities on local biodiversity, nor evaluations of the value of waste management systems to consumers through the application of benefit transfers from related willingness-to-pay studies.

These omissions are not to be regarded as trivial. For example, in the case of Trinidad and Tobago, the potential biodiversity preserved through municipal solid waste management might be assumed to be far more substantial relative to Saint Lucia, given that Trinidad and Tobago

possesses a more highly varied ecology. Furthermore, solid waste management may also be assumed to contribute more to mitigating flooding impacts in Trinidad and Tobago compared to Saint Lucia, where there is not as high a frequency of these events. These differences could possible imply a higher benefit stream to Trinidad and Tobago from waste management than was currently assessed, thus improving its benefit-cost ratio for implementing solid waste management systems.

These challenges notwithstanding, the current assessment provides a generalized estimate of the value of public sector investment in municipal solid waste management in the Caribbean.

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VII. Conclusions

The management of municipal solid waste remains a growing challenge for the small States of the Caribbean. Economic growth, along with increased urbanization, has resulted in increased waste generation per capita. Relatively weak waste-management infrastructure implies a growing threat of significant impacts on the natural environment. Poor waste management has the potential to undermine Caribbean economies, as impacts on the natural environment can affect the tourism sector over the medium to long term. Poor waste management can also impair public health and affect the productivity and well-being of the resident population.

On the basis of the present assessment, it is clear that substantial social welfare can be derived from efficient investment in municipal solid waste management in the Caribbean. In order to maximize such benefits, enhanced institutional and regulatory frameworks, a refined approach to management, and strengthened public private partnerships are necessary.

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Annex

TABLE A-1
ESTIMATION OF FULL BENEFITS AND COSTS – SOLID WASTE MANAGEMENT – SAINT LUCIA

Item - Benefits	Year 1	Year 2	Year 3	Year 4	Year 5
Avoided Public Health Damage ($US)					
Incidence of Disease					
- Dengue Fever	301	43	11	11	1
- Gastroenteritis (5 Years and Over)	1731	2354	899	992	681
Estimated Avoided Damage ($US)					
- Dengue Fever	722,099.00	103,157.00	26,389.00	26,389.00	2,399.00
- Gastroenteritis (5 Years and Over)	2,283,967.95	3,105,985.30	1,186,185.55	1,308,894.40	898,545.45
Total Estimated Avoided Public Health Damage ($US)	3,006,066.95	3,209,142.30	1,212,574.55	1,335,283.40	900,944.45
Value Parameters					
Morbidity Values/Year	2,399.00				
Value of a Statistical Life - (Mortality	97,478.00				
Percent Change in Disease Incidence from 2003					
- Dengue Fever	1				
- Gastro Enteritis (5 Years and Over)	0.55				
Preserved Aesthetic Values					
No. of Stop-over Visitors	317,939	302,510	287,518	295,761	210,348
No. of Cruise Visitors	394,364	359,593	610,345	619,680	478,346
Resident Population	161,250	162,119	162,988	163,857	164,726
Estimated Preserved Aesthetic Values					
- Stopover Visitors	12,208,858	11,616,384	11,040,691	11,357,222	8,077,363
- Cruise Visitors	15,143,578	13,808,371	23,437,248	23,795,712	18,368,486
- SLU Residents	96,653	97,174	97,695	98,216	98,737
Total Estimated Preserved Aesthetic Value ($US)	27,449,088.45	25,521,929.33	34,575,634.21	35,251,150.29	26,544,586.36
Value Parameters					
Contribution of MSWM to Overall Aesthetics (%)	0.3				
Coverage of Total MSWM Activities - SLU	0.9				
Mean WTP for Clean Environment by Local Residents	2.22				
Mean WTP for Clean Environment by Visitors	128				
Item -Costs					
Operational Costs					
Total Quantity of Wastes Handled/Year (Tonnes)	72,981.50	81,617.00	78,096.60	84,526.60	84,229.50
Cost per tonne of Waste Handled	29.47	23.46	23.46	22.95	22.95
Total Operating Costs per Year	2,150,764.81	1,914,734.82	1,832,146.24	1,939,885.47	1,933,067.03
Opportunity Costs of Land For Land Filling/Year					
Total Annual Opportunity Cost - Deglos	581,251.14	581,251.14	581,251.14	581,251.14	581,251.14
Total Annual Opportunity Cost - Veux Fort	477,917.60	477,917.60	477,917.60	477,917.60	477,917.60
Total Opportunity Costs per Year	1,059,168.74	1,059,168.74	1,059,168.74	1,059,168.74	1,059,168.74
Estimated Annual Rental Per Ha (US$0.60 per Sq. Ft)	64,583.46				
Size of Land Fill - Deglos (Ha.)	9				
Size of Land Fill - Veux Fort (Ha.)	7.4				

TABLE A-2
ESTIMATION OF FULL BENEFITS AND COSTS – SOLID WASTE MANAGEMENT – TRINIDAD AND TOBAGO

Item - Benefits	Year 1	Year 2	Year 3	Year 4	Year 5
Avoided public health damage ($US)					
Incidence of disease					
- Dengue fever	2,238	2,417	6,246	2,464	546
- Gastroenteritis (All Ages)	17,356	22,694	16,897	18,941	22,231
- Leptospirosis	171	153	181	142	136
Estimated avoided damage ($US)					
- Dengue fever	1,610,688.60	1,739,514.90	4,495,246.20	1,773,340.80	392,956.20
- Gastroenteritis (All Ages)	20,818,522.00	27,221,453.00	20,267,951.50	22,719,729.50	26,666,084.50
- Leptospirosis	246,137.40	220,228.20	260,531.40	204,394.80	195,758.40
Total estimated avoided public health damage ($US)	22,675,348.00	29,181,196.10	25,023,729.10	24,697,465.10	27,254,799.10
Value parameters					
Morbidity values/year	2,399.00				
Value of a statistical life - (mortality)	97,478.00				
Proportion of disease incidence due to waste management from 1983					
- Dengue fever	0.3				
- Gastroenteritis (All Ages)	0.5				
- Leptospirosis	0.6				
Preserved aesthetic values					
No. of stop-over visitors	398,559	383,101	384,214	409,069	442,596
No. of cruise visitors	104,061	82,272	60,047	55,532	54,254
Resident population	1,262,366	1,266,797	1,275,705	1,282,447	1,290,646
Estimated preserved aesthetic values					
- Stopover visitors	1,667,969	1,603,278	1,607,936	1,711,954	1,852,264
- Cruise visitors	435,495	344,308	251,297	232,401	227,053
- TTO residents	852,097	855,088	861,101	865,652	871,186
Total estimated preserved aesthetic value ($US)	2,955,561.75	2,802,673.98	2,720,333.16	2,810,006.91	2,950,503.30
Value parameters					
Contribution of MSWM to overall aesthetics (%)	0.45				
Coverage of total MSWM activities - TTO	1				
Mean WTP for clean environment by local residents	1.5				
Mean WTP for clean environment by visitors	9.3				
Item -costs					
Operational costs					
Total quantity of wastes handled/year (Tonnes)	466,116.00	416,662.00	467,482.00	534,816.00	583,099.00
Cost per tonne of waste handled	45.57	50.75	55.06	59.33	63.83
Total operating costs per year	21,240,906.12	21,145,596.50	25,739,558.92	31,730,633.28	37,219,209.17
Opportunity costs of land for Land filling/year					
Total annual opportunity cost - Betham	1,575,836.18	1,575,836.18	1,575,836.18	1,575,836.18	1,575,836.18
Total annual opportunity cost - Forres Park	206,667.04	206,667.04	206,667.04	206,667.04	206,667.04
Total annual opportunity cost - Guanapo	180,833.66	180,833.66	180,833.66	180,833.66	180,833.66
Total annual opportunity cost - Studley Park	161,458.63	161,458.63	161,458.63	161,458.63	161,458.63
Total opportunity costs per year	2,124,795.51	2,124,795.51	2,124,795.51	2,124,795.51	2,124,795.51
Estimated annual rental per Ha (US$0.24 per Sq. Ft)	25,833.38				
Size of land fill - Betham (Ha.)	61				
Size of land fill - Forres Park (Ha.)	8				
Size of land fill - Guanapo (Ha.)	7				
Size of land fill - Studley Park (Ha.)	6.25				

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